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# (12) EUROPEAN PATENT APPLICATION

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## (54) Continuous annealing method and apparatus for deep drawable extra-low carbon steel.

(57) A method and an apparatus for continuously annealing extra-low carbon steels are disclosed. The apparatus for practising the method comprises a heating zone, a temperature regulating zone having a large heating capacity per unit length of steel sheet and a good response, a rapid cooling zone and a final cooling zone.

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# CONTINUOUS ANNEALING METHOD AND APPARATUS FOR DEEP DRAWABLE EXTRA-LOW CARBON STEEL

This invention relates to a method and an apparatus for continuously annealing an extra-low carbon steel for deep drawing. More particularly, it relates to a method and an apparatus which can utilize excellent mechanical properties of extra-low carbon steel at maximum by taking a serious view of heating as a furnace structure as compared with the conventional furnace structure in which the most important section is cooling zone.

Heretofore, the production of deep drawable steel sheets through continuous annealing process has been disclosed in Japanese Patent Application Publication No. 47-33409. As shown by a symbol (a) in Fig. 5, this technique lies in that a coiled steel sheet after hot and cold rollings is heated to a higher temperature, soaked at this temperature for a given time, rapid cooled down to about 400°C, held at about 400°C for 1-3 minutes and then cooled down to room temperature. Furthermore, as described in the prior art of the above article, there is a technique wherein a low carbon steel is annealed by merely cooling after the heating and soaking as shown by a symbol (b) in Fig. 5. In any case, the steel sheets annealed by the above heat cycle are rigid

and are not fit for use as a deep drawable steel sheet.

Therefore, an equipment for annealing low carbon steel according to a cycle of heating → soaking → rapid cooling → overaging is only industrialized at present.

In such a conventional technique for continuously annealing low carbon steel to produce a deep drawable steel sheet, it is well-known that a cooling step is most important in the continuous annealing. That is, it is necessary to control the rapid cooling and overaging conditions, and further slow cooling conditions prior to the rapid cooling or final cooling conditions after the overaging. In the continuous annealing of low carbon steel, therefore, a serious problem is how such an ideal and complicated cooling cycle is effectively attained in the actual operation or how an equipment capable of producing the steel sheet in a high efficiency at the above heat cycle is designed. Up to the present, the continuous annealing equipments for the production of deep drawable steel sheets are designed and constructed on the basis of the aforementioned technical idea. As a result, the cooling portion in all the existing continuous annealing equipments for the production of deep drawable steel sheets is a rate-determining portion of the equipment, and the operation and control processes thereof are planned so as to preferentially attain the desired

cooling conditions. This is a natural consequence from a viewpoint of the conventional technical idea.

On the other hand, it is known that when using an extra-low carbon steel having a carbon content (C≅0.002%) less than a tenth of that of the conventional low carbon steel (C≅0.04%), the overaging treatment becomes unnecessary. While, it is considered that there is no essential difference between low carbon steel and extra-low carbon steel in a point of going through the heating and soaking steps. Therefore, the conventional annealing furnace designed for the low carbon steel is applied to the extra-low carbon steel up to now. However, the excellent mechanical properties of extra-low carbon steel can not be utilized at all in such a furnace, and there are rather caused many inconvenient points.

When the low carbon steel is treated in the conventional continuous annealing apparatus for deep drawable steel sheets as shown in Fig. 4, the control of rapid cooling rate and overaging condition is most important. In order to accurately control these factors, a temperature starting the rapid cooling or a temperature at an outlet side of a soaking zone should be constant. However, as the sheet travelling speed, sheet gauge or the like changes, the temperature in the heating zone varies as shown by symbols (i), (ii) and (iii) in Fig. 4a, and in extreme cases, the sheet heated to

a higher temperature in the heating zone is gradually cooled in the soaking zone as shown in the symbol (i) of Fig. 4a.

In this connection, the following has been found from results of experiments made by the inventors. That is, an extra-low carbon steel containing 0.0025 wt% of C, 0.08 wt% of Mn, 0.01 wt% of Si, 0.010 wt% of P, 0.005 wt% of S, 0.04 wt% of Aℓ, 0.002 wt% of N and 0.035 wt% of Ti was melted and continuously cast into a slab, which was hot rolled and cold rolled to obtain a steel sheet of 0.8 mm in final gauge. This sheet was heated at various heating temperatures, soaked for 0-120 seconds and then subjected to a skin pass rolling. Then, the elongation of the thus treated sheet was measured to obtain a result as shown in Fig. 2, wherein numerical values described in circles are values of elongation (%). As seen from Fig. 2, the elongation increases with the rise in the heating temperature, but the increase of elongation is slight at a relatively low heating temperature of 750°C even when this temperature is held for a long time, while the influence of the soaking time is not substantially recognized at the heating temperature above 800°C. The similar tendency is observed on the other properties such as yield strength, tensile strength and so on.

Then, the secondary work embrittlement in the annealing at 850°C was examined to obtain a result as

shown in Fig. 2, wherein symbol o shows no embrittlement and symbol × shows occurrence of embrittlement. As seen from the result of Fig. 2, the cracking does not occur even at -80°C when the soaking time is zero, while when the soaking is carried out for a time of not less than 30 seconds, the embrittlement temperature is as high as not lower than -50°C. From this fact, it is confirmed that it is better to make the soaking time as short as possible.

Further, the cold rolled sheet of 0.8 mm in final gauge was heated to various temperatures at a heating rate of 35°C/sec and rapidly cooled at a cooling rate of 30°C/sec, and thereafter r-value (Lankford value) was measured to obtain a result as shown in Fig. 3. As seen from Fig. 3, in case of the low carbon steel, the r-value tends to increase as the annealing temperature rises, but the change of r-value is not so large. Inversely, when the annealing temperature reaches 850°C, the rate of austenite phase increases to obstruct the growth of crystal grains and hence the r-value tends to decrease. On the contrary, in case of the extra-low carbon steel, the r-value tends to considerably increase as the annealing temperature rises.

From these results, the inventors have discovered that the control of maximum heating temperature is most important for obtaining a given product

from the extra-low carbon steel without controlling the soaking time.

Considering the case of annealing the extra-low carbon steel in the conventional continuous annealing apparatus on the basis of the above knowledge, the steel sheet is annealed according to the changed heat cycle as shown in the symbols (i), (ii) and (iii) of Fig. 4a in the heating zone as previously mentioned, so that even when the temperature at delivery side of the soaking zone is constant, there is caused a problem of changing the mechanical properties by the maximum heating temperature in the heating zone.

Since the extra-low carbon steel becomes very soft at high temperature, a risk of producing surface defects and coil breakage increases as the holding time at the high temperature becomes longer, so that a sufficient care must be taken.

It is an object of the invention to solve all of the aforementioned problems in the manufacture of extra-low carbon steel sheets and to provide continuous annealing method and apparatus capable of precisely controlling the objective heating temperature.

According to a first aspect of the invention, there is the provision of a method of continuously annealing an extra-low carbon steel for deep drawing, which comprises the steps of:

heating a sheet material of the above steel from

room temperature above its recrystallization temperature;

regulating the temperature of the heated sheet by rapidly heating to an objective maximum heating temperature, which is determined by a relation of previously set steel composition, production conditions and product properties, within an accuracy of at least ±10°C; and

rapid cooling without being subjected to a soaking and then cooling to room temperature.

According to a second aspect of the inventin, there is the provision of a continuous annealing apparatus for deep drawable extra-low carbon steel comprising a heating zone, a temperature regulating zone having a heating capability per unit length of steel sheet larger than that of the heating zone and a good response capable of attaining a temperature accuracy of at least ±10°C even at a non-steady portion, a rapid cooling zone and a final cooling zone. This apparatus is different from the conventional continuous annealing apparatus in a point that the temperature regulating zone is used instead of the soaking zone and the overaging zone is omitted as shown in Fig. 1b.

In a preferred embodiment of the invention, a preliminary heating zone is arranged before the heating zone for improving heat efficiency.

In another preferred embodiment of the invention, a zone capable of cooling during the heating

may be arranged in order to efficiently control the maximum heating temperature.

The invention will be described with reference to the accompanying drawings, wherein:

Fig. 1a is a diagram showing a heat cycle in the apparatus according to the invention;

Fig. 1b is a schematic view of an embodiment of the apparatus according to the invention;

Fig. 2 is a graph showing influences of soaking time and heating temperature on elongation;

Fig. 3 is a graph showing an influence of annealing temperature on r-value;

Fig. 4a is a diagram showing a heat cycle in the conventional continuous annealing apparatus;

Fig. 4b is a schematic view of the conventional continuous annealing apparatus;

Fig. 5 is a diagram showing a heat cycle in the conventional annealing; and

Fig. 6 is a graph showing changes of properties when the travelling speed of the decoiled sheet is changed in the course of the continuous annealing.

The apparatus according to the invention is largely different from the conventional apparatus shown in Fig. 4 in a point that the overaging zone is omitted and the temperature regulating zone is arranged instead of the soaking zone. According to the invention, it is intended to positively control the temperature while

heating the steel sheet in the temperature regulating zone, so that it is required to have a fairly large heating capacity and a good response. In this case, the heating capacity per unit length of steel sheet in the temperature regulating zone is necessary to be larger than that of the heating zone or preheating zone, and also the temperature accuracy is necessary to be at least ±10°C even at a non-steady portion. For this purpose, a means for directly blowing a high-temperature heated non-oxidizing gas to the steel sheet, a means for directly heating the steel sheet by application of current, a means for using a radiant tube at a temperature higher than that usually used and so on are adopted to the temperature regulating zone. Further, the temperature regulating zone has a function of correcting the control of mechanical properties and change of components by the annealing temperature or a function of correcting the temperature of the steel sheet by the sheet travelling speed or change of sheet gauge, whereby the objective ultimate temperature of steel sheet can be controlled with a good precision. Moreover, the feature that the steel sheet is partially cooled in the course of the heating is effective for achieving the object of the invention.

After the steel sheet is heated to the objective ultimate temperature in the temperature regulating zone as shown in symbols (i), (ii), (iii) or (iv) of Fig. 1a,

it is rapidly cooled without passing through the overaging zone. In this case, a gas jet cooling, roll cooling or a combination thereof is suitable as a cooling means. Moreover, the cooling rate is hardly restricted from a viewpoint of mechanical properties, so that it may be determined mainly by circumstances from viewpoints of installation and operation because special treatment of rapid cooling-overaging is not required.

The reason why the steel sheet is rapidly cooled after the temperature reaches the objective ultimate temperature is due to the fact that the improvement of mechanical properties is no longer expected when the soaking time becomes long as shown in Fig. 2 and conversely risks such as abnormal growth of crystal grains, degradation of properties increase and frequency in occurrence of operational troubles such as heat buckle, pick-up and so on becomes high.

In order to more enhance the heat efficiency, a preliminary heating zone may be arranged before the heating zone or the heating zone may be divided into plural furnace bodies, which does not injure the effect of the invention. Further, the feature that the cooling zone is divided into two or more cooling furnace bodies for enhancing the cooling efficiency does not also injure the effect of the invention.

According to the invention, when using an extra-low carbon steel as a sheet material, various

mechanical properties can be obtained from the same sheet material or the mechanical properties of non-steady portion in the sheet material can be uniformized by accurately controlling only the heat annealing temperature in the continuous annealing treatment. Particularly, the invention can advantageously realize the following facts:

(1) The steel sheet having very uniform mechanical properties can be obtained by controlling the heating temperature in accordance with the change of chemical composition;

(2) The degradation of mechanical properties in outer and inner portions of hot rolled coil can be compensated by local high-temperature heating;

(3) The temperature change of steel sheet due to the change of sheet gauge or sheet travelling speed can be prevented; and

(4) The formation of products having given mechanical properties from the same material.

For example, when the sheet travelling speed of the extra-low carbon steel (C:0.0015%, Ti:0.055%) is changed in the course of the annealing as shown in Fig. 6, the r-value, hot coiling temperature and heating temperature can uniformly be maintained over substantially the whole length of the sheet.

Example

In the conventional continuous annealing

apparatus having such a throughput that a product of sheet gauge (mm) and sheet travelling speed (mpm) is about 400, the heating capacity of the heating zone (burner capacity) was about $40 \times 10^6$ kcal/hr. On the other hand, the soaking zone had only a heating capacity compensating dissipation heat from the furnace body and its burner capacity was a tenth of that of the heating zone.

On the contrary, the heating capacity of the temperature regulating zone according to the invention is at least two times of that of the conventional soaking zone by using a super-high temperature radiant tube having a furnace temperature above 1100°C together with a high temperature gas jet blowing, which corresponds to $10 \sim 20 \times 10^6$ kcal/hr. Particularly, when considering the heating capacity per unit length of steel sheet, the heating capacity of the temperature regulating zone is more than that of the heating zone.

As mentioned above, according to the invention, the objective heating temperature of the deep drawable extra-low carbon steel can be accurately controlled to obtain a steel sheet having no change of mechanical properties. Further, the heat efficiency can be enhanced by arranging the preliminary heating zone before the heating zone. These improving effects are very conspicuous.

## Claims

1. A method of continuously annealing an extra-low carbon steel for deep drawing, which comprises the steps of:

heating a sheet material of the above steel from room temperature above its recrystallization temperature;

regulating the temperature of the heated sheet by rapidly heating to an objective maximum heating temperature, which is determined by a relation of previously set steel composition, production conditions and product properties, within an accuracy of at least ±10°C; and

rapid cooling without being subjected to a soaking and then cooling to room temperature.

2. The method according to claim 1, wherein said steel is partially cooled in the course of the heating for regulating the maximum heating temperature.

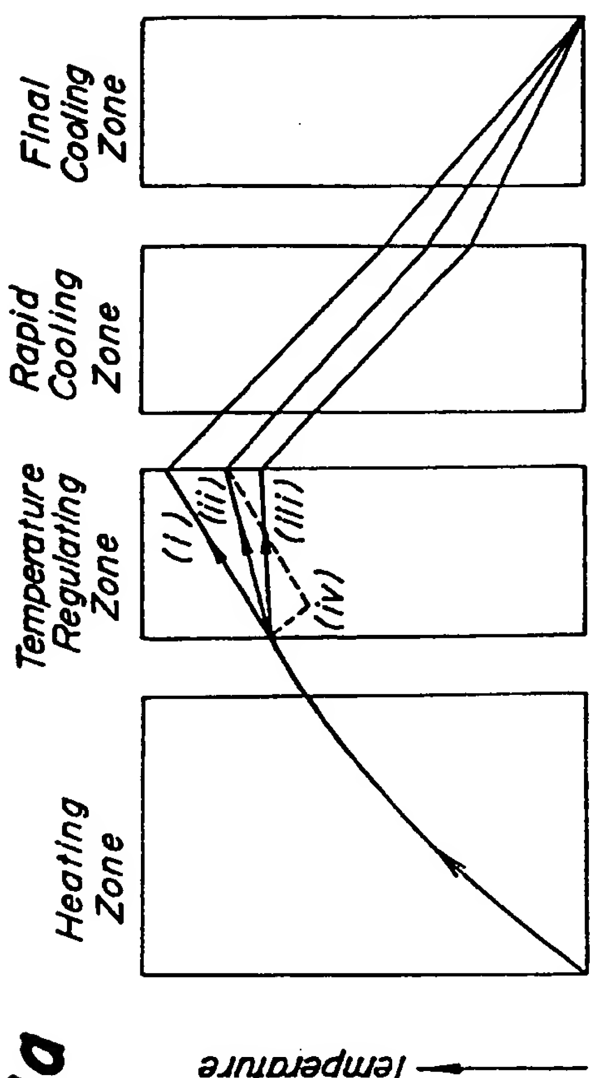
3. A continuous annealing apparatus for deep drawable extra-low carbon steel comprising a heating zone, a temperature regulating zone having a heating capacity per unit length of steel sheet larger than that of the heating zone and a good response capable of attaining a temperature accuracy of at least ±10°C even at a non-steady portion, a rapid cooling zone and a final cooling zone.

4. The apparatus according to claim 3, wherein a preliminary heating zone is arranged before the heating zone.

5. The apparatus according to claim 3, wherein a coolable zone for regulating a maximum heating temperature is provided in said heating zone or said temperature regulating zone.

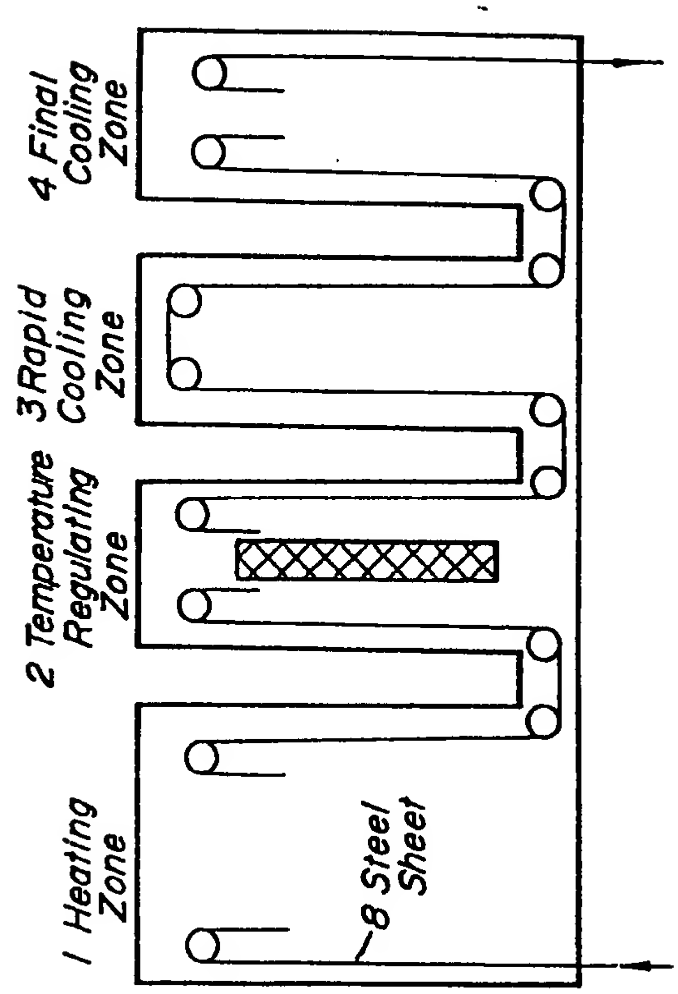
6. The apparatus according to claim 4, wherein a coolable zone for regulating a maximum heating temperature is provided in said heating zone or said temperature regulating zone.

FIG_1a



Heating Zone
Temperature Regulating Zone
Rapid Cooling Zone
Final Cooling Zone
(i)
(ii)
(iii)
(iv)
Temperature


FIG_1b



1 Heating Zone
2 Temperature Regulating Zone
3 Rapid Cooling Zone
4 Final Cooling Zone
8 Steel Sheet

FIG_2

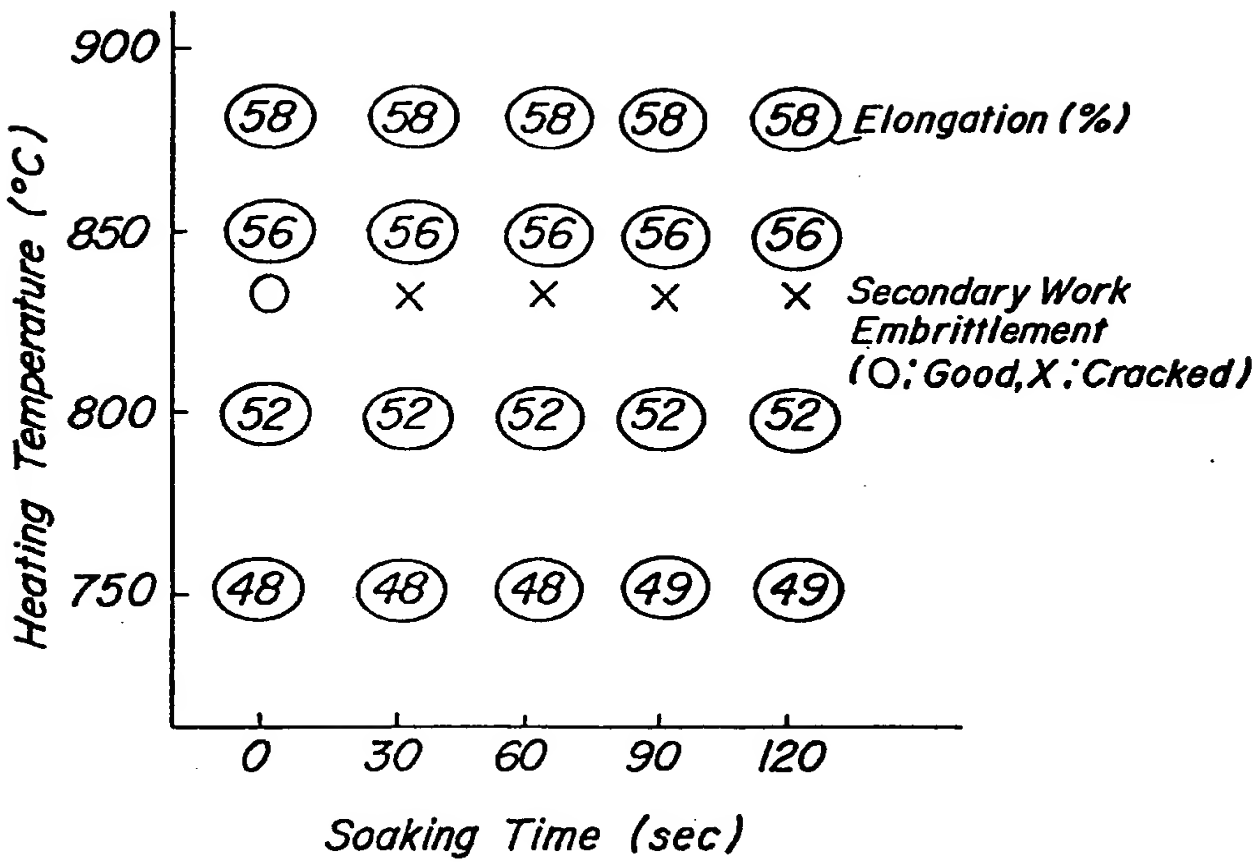

900
850
800
750
Heating Temperature (°C)
58
58
58
58
58
Elongation (%)
56
56
56
56
56
Secondary Work Embrittlement (O: Good, X: Cracked)
52
52
52
52
52
48
48
48
49
49
0
30
60
90
120
Soaking Time (sec)

FIG_3

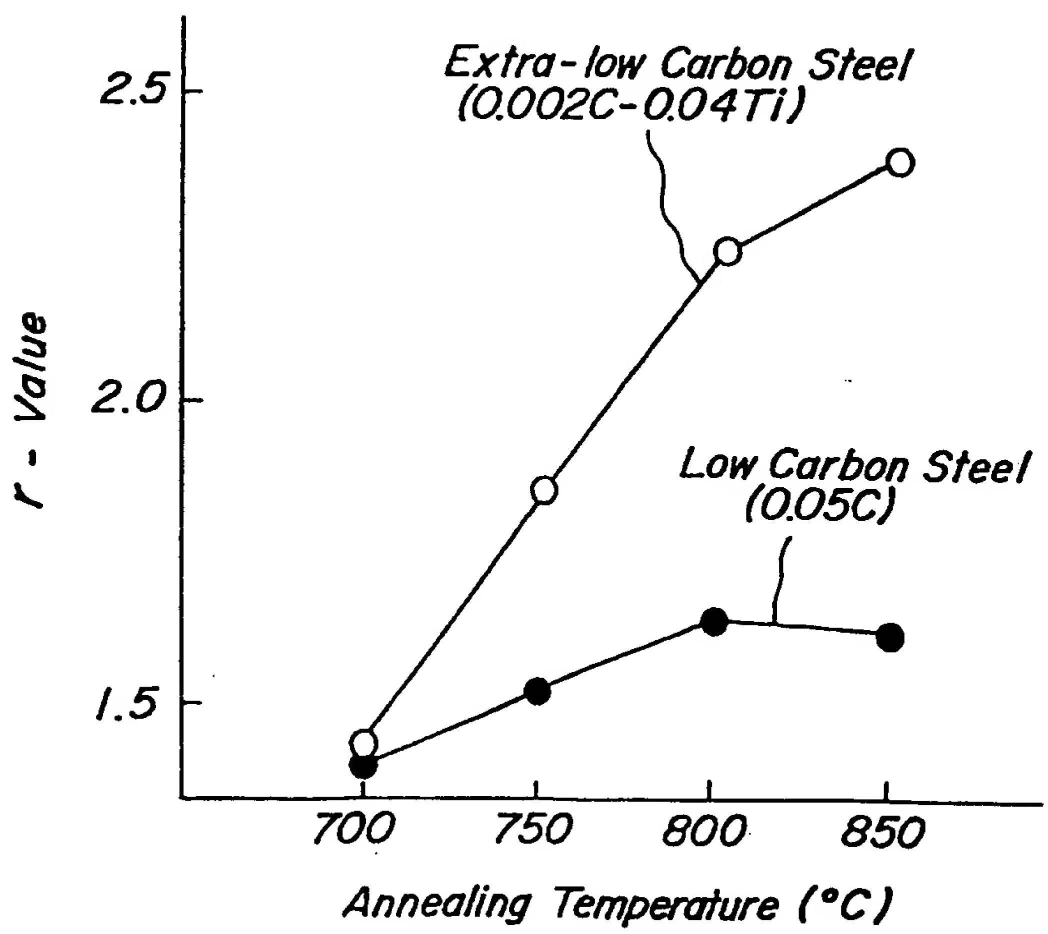

Extra-low Carbon Steel (0.002C-0.04Ti)
Low Carbon Steel (0.05C)
2.5
2.0
1.5
r - Value
700
750
800
850
Annealing Temperature (°C)

FIG_4a PRIOR ART

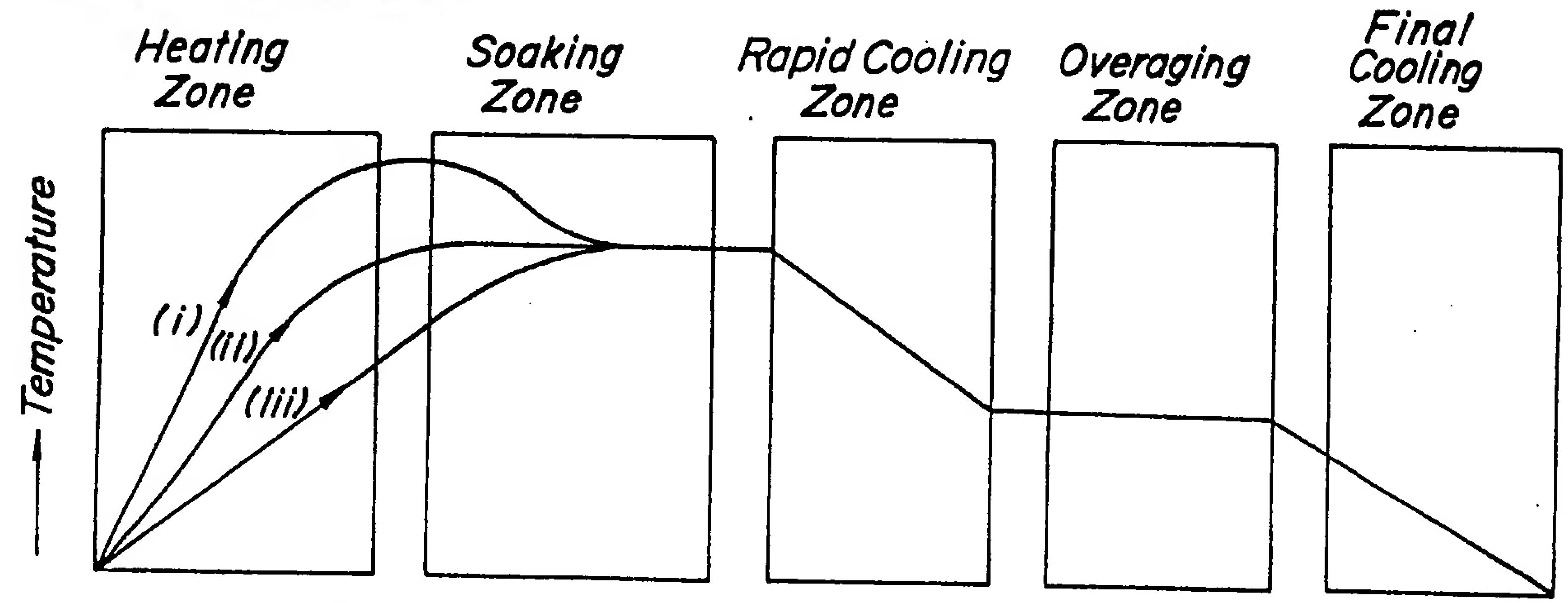
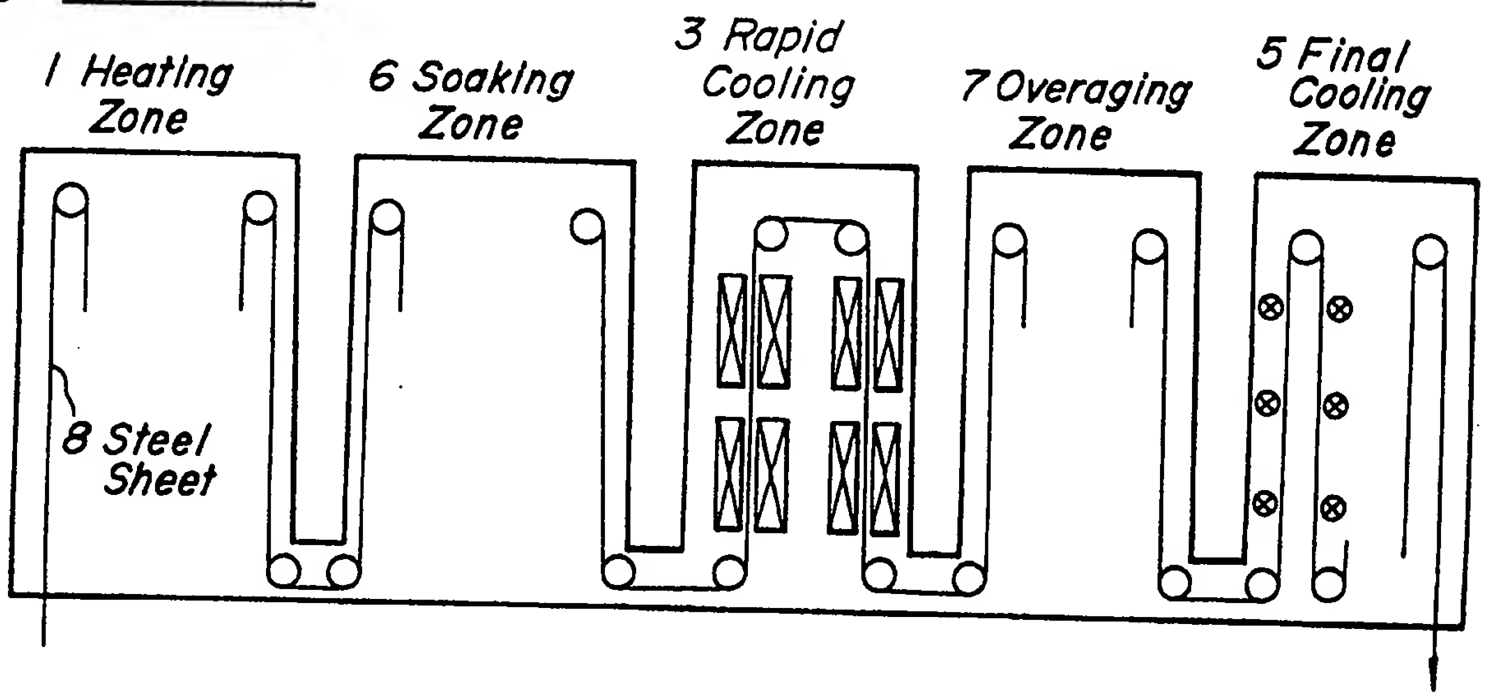



FIG_4b PRIOR ART



# FIG_5

PRIOR ART

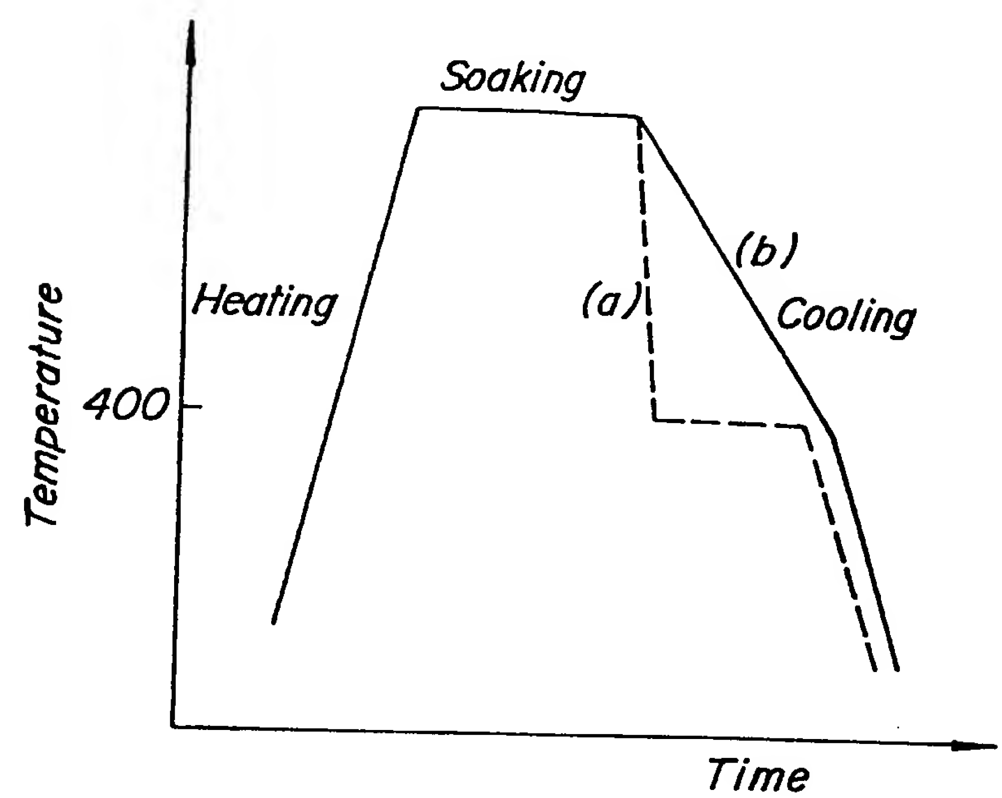


FIG_6

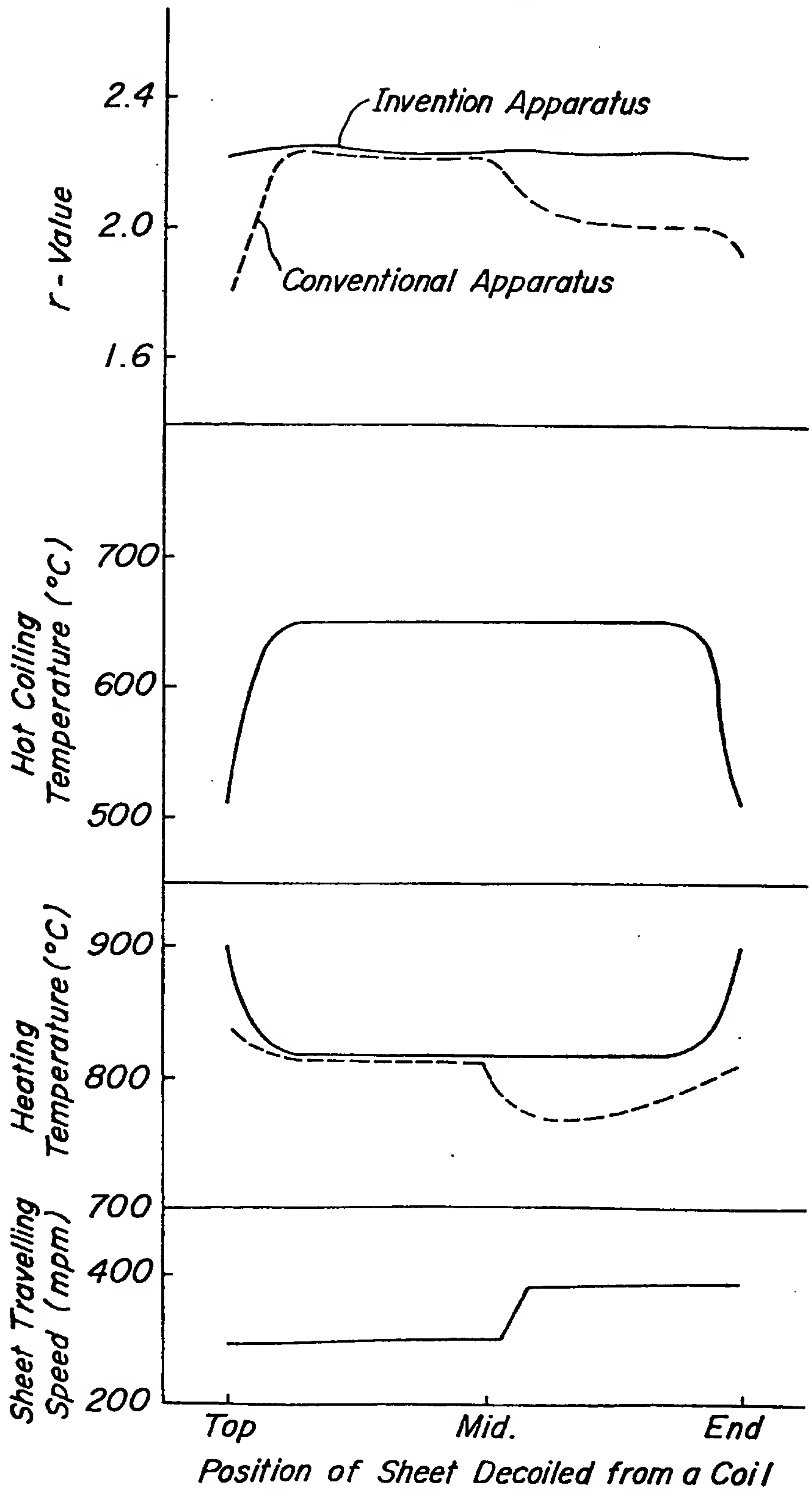

Invention Apparatus
Conventional Apparatus
2.4
2.0
1.6
r - Value
700
600
500
Hot Coiling Temperature (°C)
900
800
700
Heating Temperature (°C)
400
200
Sheet Travelling Speed (mpm)
Top
Mid.
End
Position of Sheet Decoiled from a Coil

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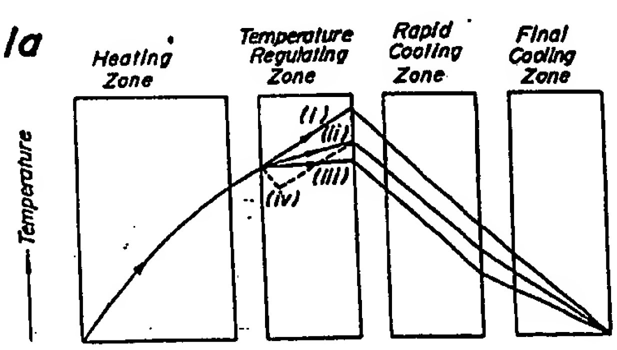
FIG_1a




EP 0 211 681 A3

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number

EP 86 30 6234

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.4) |
|---|---|---|---|
| A | DE-B-2 056 313 (NIPPON KOKAN K.K.) & JP - B - 47 33409 (Cat. D) * claim 1 * | 1 | C 21 D 9/48<br>C 21 D 9/56 |
| A | DE-A-2 942 338 (NIPPON STEEL) * claim 1 * | 1 | |
| A | EP-A-0 112 027 (KAWASAKI STEEL) * claim 1 * | 1 | |
| A | US-A-3 385 946 (D.G. HATCHARD) * figure 1 * | 1 | |
| A | PATENT ABSTRACTS OF JAPAN vol. 6, no. 180 (C-125)(1058), 14 September 1982; & JP - A - 57 94524 (NIPPON KOKAN) 12-06-82 | 1 | |
| | | | TECHNICAL FIELDS SEARCHED (Int. Cl.4) |
| | | | C 21 D |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| BERLIN | 29-01-1990 | SUTOR W |

CATEGORY OF CITED DOCUMENTS

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E : earlier patent document, but published on, or after the filing date
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L : document cited for other reasons

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